FACTORS INFLUENCING CONCRETE CURING DURING VEHICLE SECURITY BARRIER INSTALLATION

When installing Vehicle Security Barriers (VSBs) with concrete foundations, in addition to considering the specification of the concrete, the curing environment must also be considered.

Concrete specification

The VSB manufacturer will provide the test house with the concrete specification to be used for the VSB installation. Guidance on selecting the correct concrete specification is available in BS EN 206:2013(1), which should be read in conjunction with BS 8500-1:2006(2) and BS 8500-2:2006(3).

Provided the specified concrete has been ordered and delivered, the onus is on the test house to ensure that, in addition to it being placed and compacted correctly, the subsequent curing conditions are suitable. BS EN 13670:2009(4) describes the requirements for placing, compacting and curing concrete.

Concrete curing

Curing is a very important final step in the installation process because hydration takes place in this phase. Hydration is a chemical reaction between the cement and water within the concrete mix. The products of hydration develop from the surface of the cement grains within the mix and can only take place properly in water filled capillaries. The amount and rate of hydration during the curing period is dependent on the time since pour, and the moisture content and temperature of the concrete, both of which are greatly influenced by the ambient conditions.

Proper curing not only reduces the porosity of the concrete, leading to an increase in the density, it also reduces shrinkage and cracking within the concrete. Together, these factors help in achieving a higher compressive strength and better resistance to degradation and abrasion.

Given the right conditions, curing is a rapid process and a standard concrete mix with no additives will achieve approximately 60% of its specified strength within three days and approximately 75% after seven days. Curing will continue indefinitely unless the concrete dries out, which will stop hydration. The industry standard is to quote the achieved compressive strength 28 days after pouring.

Due to rapid curing early in the process, it is very important the correct curing conditions are maintained, especially during the first seven days. Extremes of temperature will greatly influence the curing process; a temperature range of 10°C to 30°C is preferable. Below 10°C, the curing process slows and below 5°C it practically stops. In addition, care must be taken when concrete is cast in winter. If the water in the concrete is allowed to freeze, the concrete will be damaged, possibly to such an extent that it will be unfit for use. Even if the temperature does not drop below 0°C, the concrete will not gain strength as quickly as it would during warmer months. Conversely, as the temperature increases this will lead to higher water loss through evaporation that will slow down, or even stop the curing process.

Important considerations

a) If the concrete is being poured onto a dry sub-base, it should be wetted to prevent it drawing moisture from the concrete. The use of a plastic membrane to cover the sub-base should be considered but for small foundations this may produce a slip plane under the foundation, leading to possible rotation issues. If used, it is suggested the foundation is keyed into the sub-base using rebar 'nails'. Alternatively, the surface of the sub-base can be sprayed with a bitumen emulsion to seal it.

b) Pouring concrete should be avoided when the temperature is less than, or is likely to fall below, 5°C.

c) Concrete must not be poured onto snow or frozen ground.

d) Sufficient vibration is required to expel all entrapped air from the concrete to achieve a denser, stronger, more durable finished slab. Insufficient vibration will leave air pockets within the concrete where no hydration can occur, which will reduce the density and compressive strength of the cured concrete. Conversely, over vibration will lead to segregation of the aggregate which may result in horizontal stratification and loss of durability, which will produce a weaker slab. It can also cause laitance, a thin layer of cement, aggregate fines and water, to form on the surface of the concrete resulting in a poor surface finish that can be prone to dusting and spalling.

e) In hot weather the rate of hydration increases. As this is an exothermic process the generated heat further accelerates the curing process. This causes temperature differentials within the concrete that can lead to the formation of plastic shrinkage cracks on the surface. Also, if curing occurs too quickly, the crystals that form through hydration fail to grow properly. This leads to a hardened cement paste that is less structured, more porous and a concrete that doesn't reach its full compressive strength. Therefore, whilst it will gain compressive strength at a faster rate than a similar concrete kept at a lower temperature, the final compressive strength of concrete kept at a higher temperature will be lower.

f) When casting large-mass pour foundations, excess heat generated by the hydration process can be a problem because it can dry out the concrete, causing the hydration process to slow down or even stop.

g) When casting in hot weather, there can be a temptation to add more water to compensate for the increased loss of water from the concrete through evaporation. Similarly, when working with a stiff mix, one with little or no slump, water may be added to make the mix more workable. In both cases, adding more water increases the water to cement ratio. As this ratio increases, the resultant compressive strength and durability of the cured concrete decreases. In addition to the loss in strength, having an excess of water can also lead to excessive cracking resulting from high shrinkage, low tensile strength and a greater risk of laitance at the surface. To increase the strength and durability of concrete, decrease the water to cement ratio.

h) In cold weather some suppliers of ready-mixed concrete are able to supply heated concrete where the aggregate and water are heated prior to mixing. Once cast, the hydration process keeps the temperature of the concrete at an elevated level but attempts must be made to insulate the concrete to reduce heat loss and prevent frost damage. For shallow foundations with a large surface area, hot concrete may not be viable due to potentially high rates of heat loss and low rates of heat generation.

i) Moisture and temperature are critical to ensuring efficient curing and several options are available to assist in maintaining these at an optimum level. There are three main methods of keeping the concrete moist, some of which also help maintain a favourable temperature:

1. Methods that maintain the presence of water in the concrete during the early hardening period. These include ponding or immersion, spraying or fogging, and saturated wet coverings such as hessian. These methods also offer some cooling through evaporation, which is beneficial in hot weather.

2. Methods that reduce the loss of water from the surface of the concrete. This can be done by covering the concrete with impervious paper or plastic sheets, or by applying membrane-forming curing compounds. White or lightly coloured sheets reflect sunlight, helping to keep concrete relatively cool in hot weather. In comparison, black plastic, absorbs heat to a marked extent and should be avoided in hot weather as it may cause unacceptably high concrete temperatures. Conversely, using black plastic in cold weather may be beneficial in accelerating the rate at which the concrete gains strength because of its heat absorption properties.

3. Methods that accelerate strength gain by supplying heat and additional moisture to the concrete. This is usually accomplished with steam and involves erecting an enclosure over the concrete, typically made from tarpaulins, then filling it with steam. Alternatively heating coils, or electrically heated forms or pads may be used in combination with the methods for maintaining the presence of water.

j) Consideration should also be given to protecting the concrete from the wind, which can reduce the temperature of the concrete and also rapidly increase moisture loss through surface evaporation. Erecting windbreaks is a solution.

k) Leaving any formwork (e.g. shuttering) in place for as long as possible also helps reduce moisture and temperature losses. In cold weather, when the rate of curing slows, it may be necessary to leave the shuttering in place longer than normal to minimise the risk of damaging the cast foundation when striking the shuttering.

References

(1) BS EN 206:2013 Concrete - Specification, performance, production and conformity.

(2) BS 8500-1:2006+A1:2012 Concrete. Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier.

(3) BS 8500-2:2006+A1:2012 Concrete. Complementary British Standard to BS EN 206-1. Specification for constituent materials and concrete.

(4) BS EN 13670:2009 Execution of concrete structures.

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